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Affective Intensity and its Effects

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Dr Jennifer Tichon

Associate Professor Guy Wallis

Associate Professor Stephan Reik

Perception and Motor Systems Laboratory

University of Queensland

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14. ABSTRACT
A new theory is proposed to account for the role of affect in understanding and evaluating performance under stress. There is no universal agreement on affect?s conceptualization or role in performance. In Affective Skill Theory (AST), affect is conceptualized as a skill that can be trained prior to an operation. As a skill, affect can also be used as a key variable in evaluating operation success based on the ability to assess the match between the affective skills of personnel with operational affective requirements. The theory has the potential to be highly valuable in supporting operational planning through identifying situations in the field which will impose high affective task demands on personnel and support assessment of the optimal affective level of expertise required of personnel to successfully complete the operation. This model of human performance conceptualizes affect as an integral component of an individual?s professional skills base. The proposal that affect can be evaluated as a skill was explored. A pilot study and associated theoretical work contribute to the literature on performance and emotion by conceptualization and subsequent measurement of affect as a skill which enables successful task completion.

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1. Background

This report is presented in the form of an executive summary attached to a more detailed discussion paper covering both the theoretical and applied findings of research undertaken at the University of Queensland with support of AOARD award number FA2386-10-1-4011.

The project commenced with the objective of developing a performance assessment tool able to measure instantaneous mood state (affect) of individuals during simulation training. The project's primary objective was to investigate affect as a measure of non-technical skills (such as decision-making) in the expectation that it would offer a more direct measure than current alternatives. During the past year the project has developed a further emphasis with affective skills themselves becoming a direct variable of interest. The objective affect measurement tool (OAMT) will allow affective skill levels of an individual during task performance to be evaluated.

The original project aims were to: Develop a method and associated theoretical framework for recognizing user affective states during simulation–based training. To validate the face-based affect recognition prototype method through application in experimental simulated training scenarios, and systematically explore feature extraction as an objective measurement approach to evaluate the impact of learner affective states on the effectiveness of complex cognitive training via simulation.

It had three original broad objectives;
a) To examine the relationships between affective intensity and cognitive learning and the impact they have on facial features, perceptual processes, physiological response and electromyographic activity.
b) To identify a reliable set of objectively measurable features and responses that highly correlates to target emotions and cognitive functions.
c) To build theoretical tools that support cognitive training in simulation initially from existing theoretical insights with novel theoretical insights added as new links are discovered in the network of associations surrounding the construct of affect.

The project plan was designed to allow for two separate pilot tests of the technical equipment:

Pilot One was undertaken at the experimental simulation laboratory located on the St Lucia campus of the University of Queensland using subjects drawn from the University population. The sole purpose of Pilot One was to achieve proof of concept and trialing/interfacing of the measurement equipment. The attached discussion paper outlines in detail the technical set-up work undertaken. While the simulator task was not as stressful as tasks undertaken during simulator training in a real world setting, measures obtained from the physiological monitoring equipment revealed that anxiety levels were reflected in a range of physiological data.

Pilot Two was to test the equipment set-up in real world simulator training setting in which anxiety and stress levels would be expected to be much higher. Successful negotiations were undertaken with a flight training program. The plan was to monitor trainee pilots drawn from a university Bachelor of Aviation Degree while they undertook testing in a flight simulator. The experiment is set up and ready to run but, unfortunately, while AFOSR IRB approval was sought in May 2010, approval has, at the time of writing, not been granted. Thus we are unable to report the results of Pilot Two in this report.

2. Affective Skills Theory

During the twelve months of the project theoretical advances were made resulting in the Affective Skills Theory being developed to explain the phenomenon whereby professionals, repeatedly exposed to high stress conditions in a simulator, can gain the affective skills to control and use their emotions to achieve high performance. The existence of affective skills was also supported by scientific findings in other fields of enquiry such as elite sport where 'affective intelligence' is terminology used to describe the ability to remain in control of emotions. The field actively promotes the channeling of emotions to facilitate optimal performance.

In Affective Skill Theory (AST), affect is therefore conceptualized as a skill that can be trained prior to an operation. As a skill, affect can also be used as a key variable in evaluating operation success based on the ability to assess the match between the affective skills of personnel with overall mission affective requirements. The theory has the potential to be highly valuable in supporting operational planning through identifying situations in the field which will impose high affective task demands on personnel and support assessment of the optimal affective level exhibited by experienced personnel able to successfully complete the operation.

3. Affective Skills Theory in Workload Prediction and Operational Planning

Real-time monitoring of individuals for affective skill capacity via an approach based on sampling multiple neurophysiologic signals, and integrating those signals with a performance prediction model able to estimate the affective component of workload, potentially provides a new method of supporting command and control personnel.

A number of workload prediction models have been developed and are currently in use within defense. To date, predictive workload measures analyze a task/workload estimating cognitive, psychomotor, auditory, kinesthetic, visual and sensory components of workload for each task. To our knowledge, no current prediction models analyze the affective cost of an operation.

The Affective Skill Theory developed in the first phase of the current AOARD project supports the development of a predictive workload measure able to estimate affective workload. By conceptualizing affect as a professional skill that can be trained prior to an operation, affective skills are recognized as a key variable when assessing both performance and workload. Being able to determine the overall affective costs of a planned mission has significant potential to

assist command and control in the area of operational planning. For example, a model of task workload which accounts for affective output (the affective costs of a deployment) will support the identification of situations in the field which will impose high affective task demands on personnel. When an operation has been identified as high in affective demand, the optimal affective level of expertise required of personnel to successfully complete the operation can be estimated. Ultimately, such a theoretical model that facilitates the mapping of affective requirements and cost with task demands could assist in predictions of overall mission success and in the planning of additional training requirements.

This new direction in operational planning support relies on the development of the objective affect measurement tool (OAMT) occurring concurrently with the development of a predictive computational affect workload model (CAWM). Affective state is a key variable within computational prediction models currently under development at UQ which will ultimately be able to offer predictions about the relationships between task demands, task performance, affect and their impact on the achievement of specific goals. This is an innovative approach involving the development of a quantitative model to translate the qualitative compensatory control model of human performance under stress and high workload (Hockey, 1997) into a computational form. The compensatory control model proposes that physiological and affective responses are inherent in the regulatory process.

Affective state is considered to be an integral aspect of a person's response to increased task demands. Traditionally, psychological models have been based on verbal descriptions of the relationships between individual factors, including affect, that influence the human response to a given set of task demands. These models allow qualitative descriptions of human performance, but do not allow quantitative assessment to be made. The central innovation of the CAWM approach is in the explicit representation of the variables within the compensatory control model as mathematical functions which will enable testing to determine their precise relationships. This application of AST is discussed further in Section 7.3 of the following discussion paper.

Affective Skill Theory (AST): A new explanation for the role of affect in evaluating performance

Abstract

This paper proposes a new theory to account for the role of affect in understanding and evaluating performance under stress. Although affect is recognized as a determinant of performance there is no universal agreement on its conceptualization or role in performance. In Affective Skill Theory (AST), affect is conceptualized as a skill that can be trained prior to an operation. As a skill affect can also be used as a key variable in evaluating operation success based on the ability to assess the match between the affective skills of personnel with operational affective requirements. The theory has the potential to be highly valuable in supporting operational planning through identifying situations in the field which will impose high affective task demands on personnel and support assessment of the optimal affective level of expertise required of personnel to successfully complete the operation. This model of human performance conceptualizes affect as an integral component of an individual's professional skills base and in the same way as a cognitive or physical skill it contributes to whether a task can be successfully completed under high stress conditions. The proposal that affect can be evaluated as a skill was explored during a preliminary pilot study during which participants affective states where evaluated undertaking a driving simulation. During the study preliminary technical work was undertaken which forms the basis of future work to develop an objective tool for measuring individual affective skill levels during simulation training. The pilot and associated theoretical work contribute to the literature on performance and emotion by conceptualization and subsequent measurement of affect as a skill which enables successful task completion.

1. Introduction

Active cognition during complex operations is critical component for success in military operations. Objective judgment and decision-making are crucial operational functions which rely on higher-order cognitive pathways to process. Emotions associated with stress such as fear and anger unless they are controlled can overwhelm prefrontal cognitive processes (Russo et al., 2005). The ability to control emotion varies across personnel and often relates to experience. An expert can be viewed as having developed over time and through experience the level of skill required to control his/her emotions during high stress operations.

A significant amount of research has been published over the past 4 decades concerning the mechanisms that underlie expert performance (eg Chi, Glaser & Farr, 1988, Ericsson et al, 2006, Lfot et al, 2009). From a practical perspective, understanding expertise is important for the design of training programs and from a theoretical perspective, the principles and mechanisms proposed to underlie expertise can be used to evaluate the generalizability of broader theories about basic cognitive processes and capacities and thus explain human performance more generally" (Loft et al, 2009).

Affect is recognized as a determinant of performance (Gee, 2010). However generally studies have examined the influence of goal striving on affective states (Foo et al, 2009, Koestner et al, 2002; Louro et al., 2007), rather than the ability of affect to influence goal striving. Ballard (2009) found that performance during a two-minute time period was positively related to affective state at the end of that time period. Reinforcement sensitivity theory (Gray 1990) predicts performance will effect tense and energetic emotional arousal most strongly. Control theory (Seo etal, 2004) makes predictions on what effect performance progress will make on affect. For example, when individuals experience activated states, such as stress or alertness, they subsequently try harder. In summary these theories suggest when making good progress toward a goal an individual experiences positive affect such as happiness and alertness; while making poor progress results in negative affect such as stress (Ballard p40, 2009). Each of these theories looks at the effect of performance on emotion.

Ballard (2009) however in addition to investigating the effect of performance on affect, also examined the effect of affect on effort during goal striving. Ballard found, "when an individual is setting a goal, feelings such as alertness or brightness can lead them to engage further and set a more difficult goal. On the other hand, feelings of anxiety or stress can lead them to avoid difficulty by setting a goal that is easier to attain. However, this process changes during goal striving, because once the individual has committed to a goal, the goal becomes more difficult to change. As such when an individual is striving toward their goal, they may respond to feelings of anxiety or stress by increasing their effort in order to regain their progress toward the goal (2009; p47)." This suggests that in fact affect can be an influential force within effective performance rather than merely being a viewed as an output that is influenced by how well or not an individual is performing in terms of progress toward their goal.

Considerable evidence shows that achievement goals and affect are intricately related. However, within the goals literature researchers have conceptualized affect as both an outcome of goal

pursuit (eg. Pekrun, Elliot & Maier, 2006) and as an antecedent of goal adoption (eg Elliot & Thrash, 2002). Thus again affect is viewed sometimes as an input, it influences goal adoption, but also as an output, it is an outcome of goal pursuit. Several models detailing possible relationships between goals, affect and performance have been proposed (eg Linnenbrink & Pintrich, 2002; Pekrun et al., 2006).

Daniels, Stupnisky, Pekrun et al, (2009, p954), proposed a sequential model in which initial affective experiences predict goals, goals predict discrete emotions, and discrete emotions predict achievement. By design, the model suggests that the relationships between constructs that occur early in the model (ie, hopefulness and helplessness) with those that come later in the sequence (ie. Enjoyment, boredom, anxiety) are at least partially mediated by the interceding constructs (ie mastery, performance goals). So again, a mix of conceptualizing affect as an input and an output of performance.

A model which locates affect in the context of mental workload is the Compensatory Control Model (Hockey, 2005). This model recognizes that physiological and affective responses are inherent in the regulatory process. For example the model explains anxiety as an output of an individual's action monitor. Affect, in this example is a result of the appraisal that current goals are not being met. When making predictions about performance under stress and high workload the model describes positive affect as decreasing when task demands increase. There is no firm prediction about negative affect under high task demands, but it suggests negative affect is most likely to increase. Thus an individual's adoption of an approach or avoidance orientation may influence the expected affective output of performance goal striving (Fletcher, 2010).

The limitation of this model and each of those outlined earlier is the limitations they impose on themselves through restricting predictions of how higher task demands will effect affect rather than how individual affective skills can or will effect goal commitment and achievement. The Affective Skill Theory (AST) provides an important new direction in theory through changing the conceptualization of affect in mental workload models, models of goal achievement and goal striving to examining affect in terms of what this variable brings to the relationship between individual appraisal of workload and ultimate achievement of goals. Conceptualizing affect as a skill that is brought by an individual to their work environment and used to achieve high performance outcomes, as opposed to conceptualizing affect as an output influenced by performance, provides a theoretical model from which prediction of a professional's likelihood of goal achievement via measureable affective skills can be made.

2. Affective Skills Theory

The work of Damasio (1995) in neuroscience has convincingly demonstrated the interdependence between emotions and activities previously considered to require only rational thought, such as problem-solving and decision-making. In Lazarus's (1966) transactional model of stress, people appraise task demands in terms of their own resources to cope. A professional needs to perceive they have the individual affective resources to cope with their workload. This perspective support the conceptualized of affect as a further resource that can act as an input to support cognitive processing. While the role of affect has been increasingly recognized in psychology, few theoretical models address the concept of affect that contributes to whether a task can be successfully completed under high stress conditions. Primarily affect has been conceptualized as an output of too many task demands such as feelings of anxiety being the result of work overload.

At the same time as models of affect conceptualize the variable as an output, simulation training for professionals working in high stress environments have been training individuals to learn to control and use their emotions to facilitate optimal performance for many years. If one is going to harness the strengths of affect to provide more effective training and increase the likelihood of success in operational settings characterized by high task demands, then theoretical models must go beyond conceptualizing affect as merely a result or output of high task demands. Emotion prepares individuals to respond to eliciting stimuli by coordinating a system for responses: anger prepares body to fight, and fear prepares it for flight (Matsumoto & Wilson, 2008). Simulation training works on the premise that a professional's confidence in his/her affective skills can be strengthened through training whereby they have been given the opportunity to experience mastery while in a highly aroused state, for example they have been able to work through fear and successfully translate it into high goal performance. Additionally, emotions help individuals identify associations between event-based triggers and behavioral consequences so as to be better equipped in similar situations in the future (Matsumoto & Wilson, 2008). As a resource that supports identification of prior experiences, emotions are clearly a resource that can be brought to bear by individuals either in the training or operational context.

The AST approach proposes that emotions that typically strengthen and support performance are 'affective skills' and that these skills are as integral to performance as technical and cognitive skills. Affective skills can be understood as new addition o the non-technical skills set. The current project commences the work to develop a construct definition for 'affective skills' and build a conceptual framework which describes how it is used to successfully attain professional

goals. This construct will cover awareness and control of emotion across both arousal and valence.

Affective skills are a concept that has been recognized in the field of professional sport for some time. Affective Intelligence is a subscale of a tool developed to measure ‘mental toughness’ in athletes. Affective intelligence recognizes that optimal performance on the sports is dependent on an athlete being able to remain in control of their emotions, no matter what obstacles they encounter and be able to be actively able to bring their emotions into play to facilitate optimal performance (Gordon & Gucciardi, 2010; Gucciardi & Gordon, 2009; Connaughton et al., 2008).

Some research has reported that motivation to achieve can only be positively influenced by emotions that are perceived to be ‘positive’. Positive affective experiences facilitate the retrieval of positive self- and task-related information, whereas negative affective experiences facilitate the retrieval of negative self- and task-related information (Linnenbrink & Pintrich, 2002; Daniels et al, 2009). However, unpleasant activated states have also been shown to be motivating during goal striving because they lead individuals to mobilize effort (Ballard, 2009). There are likely to be situations in which too much unpleasant activation is detrimental to motivation. There will be individual differences in how much unpleasant activation is too much before individuals start to lose motivation. It has always been a goal of simulation training to gradually expose trainees to increasing levels of stress until they are able to tolerate a significantly higher stressful state before they start to withdraw effort. The goal of training is to provide the opportunity for trainees, through repetition, to prove to themselves that they can maintain optimum performance under highly stressful conditions and that they do not need to withdraw but they can use their emotions to support their own performance.

Conceptualizing affect as a skill that plays an important role in performance also recognizes its role in supporting and strengthening cognitive and technical skills. If anxiety and fear are not controlled and used to support performance they inevitably degrade and undermine performance both at a technical and cognitive skills level. The AST approach could provide the basis for the development of a model that can predict the effect of different affective states on cognitive processing during high task demands. For example, when conceptualized as an input, affect can be investigated to determine the optimal degree of affective intensity to support decision making under stress.

In military operations the potential usefulness of the AST approach would be in the assessment of combat affective readiness and in the prediction of affective performance. The relationships between affect, cognition and performance support further predictions of overall performance. The ability of monitoring techniques to predict overall cognitive/affective readiness before an actual operation can provide useful logistical information regarding fitness for duty (Russo et al, 2005). If decrements are identified planning can be undertaken to more closely align cognitive/affective reserves with essential tasks or training targeting shortfalls can be undertaken if prior to operational undertaking.

3. Training Affective Skills

There are many advantages to being able to train a professional to improve their affective skills. Military reports indicate that the overwhelming majority of combat personnel experience fear before and/or during battle. Often physical symptoms associated with fear are reported such as nausea and heart palpitations. Although fear is natural and often important to survival it can't be allowed to manifest to the extent that it interferes with and reduces combat effectiveness (Redden et al, p565).

Keeping a clear head in time of crisis is critical. Many professionals across a multitude of high-stress domains including the military, police and accident response teams face such situations. Training higher-order mental abilities now most often involves computer driven simulators. The advantage of simulators, which have been in widespread use since the early 1980s, is that they allow trainees to practice extreme worst case scenarios. While reinforcing important technical skills simulators are also teaching trainees something more important: how to draw on an optimal blend of reason and emotion. They learn how to ignore their fear when fear isn't useful and how to make quick, complicated decisions in the most fraught situations (Lehrer J, 2009). Psychological skills training programs teach techniques and strategies used to assess, monitor and adjust thoughts and feelings to produce mental states that enhance performance (Vealey, 2007; Gordon & Gucciardi, 2010). Simulators provide the opportunity to put these skills to the test through the opportunity to practice the achievement of goals while under stress.

Soldiers must make complicated battlefield decisions; however, no matter how difficult or unprecedented the problem, a highly trained professional has the ability to look past primal emotions and carefully think about how to proceed (Lehrer, 2009). All indications are that there does in fact exist a skill set, best described as affective skills, that professionals are aware of

within themselves and able to bring to bear to achieve high demand goals. In aviation, pilots have long been taught to practice staying calm (Lehrer, 2009). They are able to do this through the opportunity simulators provide to practice building confidence.

However, despite the aviation industry's success in achieving continual improvements in safety, the identification of Non-Technical skills (NTS) as a root cause in many accidents has remained a problem. It is clear that the industry is making attempts to address this problematic situation, as seen by the push to implement NTS training and assessment to counter the unfortunate effects of NTS deficits. However, the assessment of NTS is still seen to be challenging. No model or framework has yet been devised that is able to be effectively used in practice.

Mavin (2010) through an investigation of the criteria used to assess pilots' performance examined individual check captain's personal evaluation criteria. Significantly, check captains identified that the first element of the decision making process was having the confidence to be able to make decisions. A candidate could fail if they were viewed as being unable to take the final step in taking responsibility or demonstrated uncertainty in decision-making. The ability to take charge of the situation was the first important step for command. The pivotal and essential role affective skills play in this ability is demonstrated in the following quote: *I've always believed that flying aero planes is nothing more than an exercise in self-confidence* (Mavin, 2010 p100).

4. Measuring Affect

In research which evaluates simulator training of cognitive skills such as situation assessment and decision-making, affective state has therefore become a key variable of interest (Tichon, 2010). However, as has been the experience in aviation, across all professional domains the assessment of NTS is challenging.

The current AOARD project (104011) was devised to identify a reliable set of objectively measurable features and responses that highly correlate to target emotions via eye-tracking, facial feature-extraction and electromyography (EMG) technologies. In trying to achieve this it has become apparent that existing theories have limits in terms of explaining the link between affect and performance. The relationship between these two variables does not seem to have

been previously investigated at all within the context of affectively intense simulator-based training settings.

All studies on affect and performance discussed earlier in this paper are characterized by one major limitation. That is, that all research is currently constrained by the necessity of relying on subjective self-report measures to measure affect. While technical performance can be measured objectively, to date affect cannot.

Subjective measures of stress include interviews, open-ended and scaled response questionnaires. “Subjective measures are particularly useful as a means to assess person-environment ‘fit’ based on direct subjective report of stressful experience. However, great caution should be exercised in using subjective self-report measures to assess stress in other domains and purposes. For example, if a researcher is interested in evaluating stress produced by a particular situation, subjective measures may be misleading. An environment perceived as stressful by one individual may not be perceived as stressful to another,” (Redden et al, 2004; p554).

When monitoring the effects of stress the military prefer objective measures. Currently physiological measures are preferred because most are fairly simple to obtain, easily quantified, and generally more objective than either self-report or behavioral ratings. For example salivary cortisol and salivary amylase provide a quick, non-intrusive and inexpensive means to predict plasma catecholamine levels (e.g. norepinephrine) under stressful conditions (Chatterton et al., 1996). The Army Research Laboratory’s salivary amylase collection protocol is simple and easy enough to be managed in a field setting (Blewett et al., 1994). Heart rate and blood pressure are also simple, quick and useful metrics to study or monitor the effects of stress (Redden et al, p553). The Army when assessing measures for use in the field obviously look for those that offers a combination of being lightweight, easily transportable and quickly and easily obtained from participants.

Simulators provide the advantage of being able to replicate high stress operational environments safely and realistically. Within these replicated environments the opportunity arises to test and develop more advanced measures. Contemporary research into the effects of mental and physical workload refer to psycho physiological measures such as electroencephalography (EEG), cardiac changes (heart rate, blood pressure), ocular events (number and duration of eye blinks), changes in skin response, muscle activity (electromyography: EMG) and respiration (Redden, 2004). Increasingly it is being recognized that capturing behavioral data from participants such as facial

expressions or head movements may be a more accurate representation of how and what they feel and a better alternative to self-report questionnaires that are not only subject to bias but also interrupt participant's affective-cognitive processes (Reynolds & Picard, 2004; Ahn et al 2010).

Feature extraction as an objective measurement tool for affect recognition has been garnering the most significant increase in interest (Liao etal, 2006; Bailenson et al., 2008). Stress has been a key variable of interest with investigations revealing features are potentially sensitive and robust to stress (Liao et al.,2006), however a model using physiological measures in tandem with facial tracking was found to be more reliable than one relying on either cue alone (Bailenson, 2008).

Bailenson's (2008) model was developed using videotapes of subjects' faces, from which trained coders made second-by-second assessments of sadness or amusement, in conjunction with physiological measurements, including cardiovascular, somatic and electrodermal responses, to predict emotion. Learning algorithms were then used to link facial anchor points, as determined by NEVEN vision which had 53 facial features, and physiological responses to emotional responses rated by the coders. From these data sources the researchers developed an accurate model of how emotions were expressed in response to the stimuli under study.

El Kaliouby & Robinson (2005) developed a general computational model for facial affect inference and have implemented it as a real-time system. This approach used dynamic Bayesian networks for recognizing six classes of complex emotions. Their experimental results demonstrated that it was more efficient to assess a human's emotion by looking at the person's face historically over a two second window instead of just a current frame. Their system was designed to classify discrete emotional classes as opposed to the intensity of each emotion.

Yoshie et al (2008) examined the relationships among psychological stress, electromyographic (EMG) activity, and performance in pianists. EMG activity was reported as a reliable, objective measurement of the underlying target construct, emotion. In response to stress, both agonist and antagonist muscle activity increase resulting in co-contraction and increased joint stiffness. Elevated muscle activity associated with psychological stress also results in increased force outputs and can lead to deterioration in overall signal-to-noise ratio in the motor control system resulting in further observable, recognizable patterns of motor performance (Yoshie et al, 2008).

The most recent work investigating applications of automatic facial detection indicates that future behavior can be successfully predicted based solely on facial expressions. Facial expression recognition is a bottom-up approach in which the correlation between facial

movement and a particular output (a behavior or an emotion) becomes the formula for establishing not just a classification model but a prediction model as well. Based only on the raw data of facial feature movements, models have been developed which successfully classify different emotions and were subsequently able to predict whether a consumer would purchase a product or not and predict whether a driver would be involved in an automobile accident before it happened (Ahn et al., 2009).

In terms of published studies on evoked emotions, research in this area has been limited by its reliance on individual subjective coders and the use of passive non-interactive movies to evoke emotion in participants (Bailenson, 2008). Immersion in replicated high stress operational environments via simulation provides a far superior research opportunity for progressing investigation into feature extraction and its correlation to affective states. The current research aims to systematically explore a combination of feature extraction, EMG and physiological measures as the first stage in the development of an objective measurement approach to evaluate learner affective states during complex cognitive training via simulation.

5. METHODS – PILOT TEST ONE

A pilot study was conducted in May 2010. This pilot was undertaken in a university laboratory setting to achieve proof of concepts and physical equipment trialing. The objectives were two-fold: (i) test the hardware and software setup with the aim of ironing out any problems, and (ii) to obtain simultaneous physiological and subjective affect measures. Although the data was used to probe for correlations between the physiological state and reports of emotional state, the primary aim of the first pilot was to check all programming requirements had been undertaken to ensure all monitoring equipment was functioning as required by the study and were appropriately synchronized with each other. Additionally it provided a trial set of data for filtering and making initial analytical sweeps to assist determine final analysis requirements. A second Pilot Test was then to be undertaken with trainee commercial pilots in a full flight simulator with this second round of data being primarily used to identify initial physiological indicators of emotional state. Unfortunately, having submitted Human Use Documentation seeking approval to use the flight simulator on 27th May 2010 the approvals had not been received by the end of the 12 month project time. Therefore Pilot Test One only will be reported here.

In Pilot Test One muscle activity is recorded by electromyography (EMG) and feature extraction via eye responses using an eye-tracker. The study used a driving simulation in which subjects

had to steer through a sequence of obstacles. The test consisted of four road segments. After completing each segment the simulation was halted and the user was required to fill in a questionnaire assessing their affective state.

5.1 Participants

Volunteers were recruited from the post-graduate student and staff population at the University of Queensland's School of Human Movement Studies. Prerequisites for participation were normal or corrected-to-normal vision and being licensed to drive on Australian roads. Five subjects took part in the study ranging in age from 26 to 51 years.

5.2 Apparatus

5.2.1 Simulator

The experiments were conducted in a fixed-base driving simulator, which consists of a Silicon Graphics (SGI) Onyx 3200 graphics system, Barco 808S CRT projector and Logitech MOMO force-feedback steering wheel. The steering wheel is controlled by a Dell Pentium 4 PC, which shares a high-speed ethernet connection with the graphics computer. Scenes are rendered by custom OpenGL Performer software and front-projected onto a flat, matte white surface 3.4m wide by 2.7m high, which subtends 78 by 68 degrees of arc at a viewing distance of 2.54m. Vertical update and software update rates are fixed at 72Hz, and pixel resolution is 1280x1024 with 32-bit color depth. The steering wheel turns through 240 degrees (-120deg to +120deg) and produces a return force proportionate to angular rotation. Steering-wheel angle is sampled at each vertical update.

5.2.2 Virtual Scene

A virtual environment consisting of a winding road was used for the pilot test simulation. The roadway generated in each of the four segments of a single test consisted of 7 continuously linked sections. The order (and direction) in which each curve was encountered was randomized on a trial-by-trial basis. Randomization of curve magnitude and direction were intended to eliminate systematic sources of variability in performance. Figure 1 shows views of the roadway from the participants' point-of-view encountering four different levels of obstacle obstruction.

5.2.3 Electromyography (EMG)

EMG data were recorded at 1000Hz using surface electrodes feeding into a National Instruments analogue recorder that is controlled by a LabView program running on a central PC (Control PC). Eight synchronous analogue recording channels were available.

The activity of the following muscles were of interest and were recorded:

1. Jaw clenching (*masseter)*.
2. Shoulder tension muscles (*upper Trapezius*).
3. Wrist flexing.(*Flexor carpi radialis).*
4. Calf tension (*Lateral gastocnemius*).
5. Thigh tension (*Vastus lateralis).*

It was our intention to also record eyebrow movement (*Corrugator supercilii*) but it proved too difficult to attach electrodes effectively without interfering with the eye-tracker head harness.

5.2.4 Feature Extraction via Eye tracking and Pupilometry

Eye movement and pupil size data were be recorded using an SR Research EyeLink II head-mounted tracker, performing binocular 500Hz sampling. The eye tracker is connected to a dedicated PC (the EyeLink 'host PC') that has custom hardware, on a PCI card, to communicate with the eye tracker and collect its data. The EyeLink II system also requires a second "display PC" which manages interaction with the subject using the eye tracker. The host PC effectively acts as a peripheral to the display PC.

Data collected by the eye-tracker includes relative pupil size, eye position and movement velocity. The final data includes some derived "events": blinks, fixations and saccadic movements that are calculated by the eye-tracker host before it sends the data file to the display PC. This data file is accumulated on the host PC and transmitted at the end of a session.

The eye tracker requires an initial calibration procedure for each participant. During this the subject is fitted with the head harness, and then responds to fixed stimuli, enabling the eye tracker software to calculate how to extrapolate from eye movement and position to gaze direction for the individual subject.

Feature measures which were derived from the eye-tracking data were: Blinking Frequency (BF), Average Eye Closure Speed (AECS), Percentage of Saccadic Eye Movement (PerSac), Gaze Spatial Distribution (GazeDis), Percentage of Large Pupil Dilation (PerLPD),

5.2.5 Survey

A self-report survey was used in this initial stage to gain an indication from participants of those emotions that were engendered by the test simulation. A suitable general measure of emotional states was ascertained to be the Multiple Affect Adjective Checklist (MAACL-R) which has been extensively used in the investigation of the impact of stress on psychological functioning (Hunsley, 1990) and is currently in use in simulator training evaluations. In studies of acute stress, the Army Research Laboratory (ARL) has found that temporary stress effects such as anxiety, depression and hostility are revealed by the Multiple Affect Adjective Checklist-Revised (MACCL-R). The checklist consists of 132 adjectives that comprise five primary subscales (anxiety, depression, hostility, positive affect, and sensation seeking). The checklist can be completed in approximately five minutes (Redden et al, 2004). The drawback of the scale is that it more easily achieves independence between positive and negative affect rather than between two dimensions of negative affect, however the goal is to use the items as a starting point from which to commence the research enabling later theoretically derived dimensions of affect to be identified enabling reliable differentiation.

5.3. Data Synchronization

In order to investigate correlation between affect state and all the physiological data the various data streams had to be synchronized. In this experiment the eye tracker data, recorded as a sequence of data records time-stamped to an accuracy of 2ms, and the EMG data, recorded at a sample rate of 1000Hz per second, needed to be synchronized prior to analysis.

The eye tracker library has a routine to set/unset its host's parallel port data lines, and when it does so it logs the action as a time-stamped message in its data file. This mechanism was used to achieve timing synchronization between the eye tracker and EMG data by routing one of the parallel port lines of the eye tracker host PC to one of the analogue data channels on the EMG recorded. Setting or dropping the TTL voltage on this line via the eye tracker control program,

- sets a time point in the EyeLink data via the timestamp of the action message, and
- Records a step-change in the value recorded by the monitoring channel, which is aligned with the EMG data recorded on the other channels.

The margin of error in this mechanism was the delay between the EyeLink II host recording the output action message and the change in voltage initiated by that action reaching the analogue recorder and affecting its output. It was judged that this was not significant in terms of the 2ms accuracy of the EyeLink data itself.

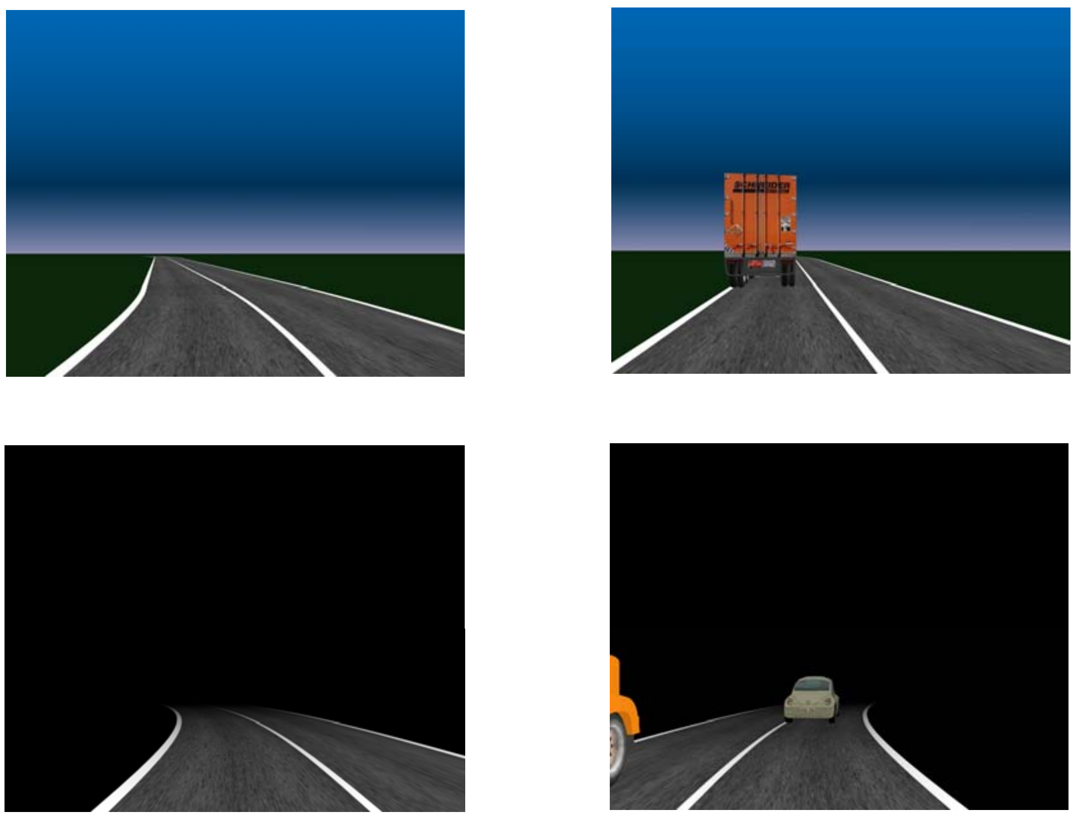


Figure 1: Example scenes from the roadway a) Open road. b) Truck blocking lane. c) Nighttime/restricted viewing. d) Unexpected oncoming vehicle while passing truck.

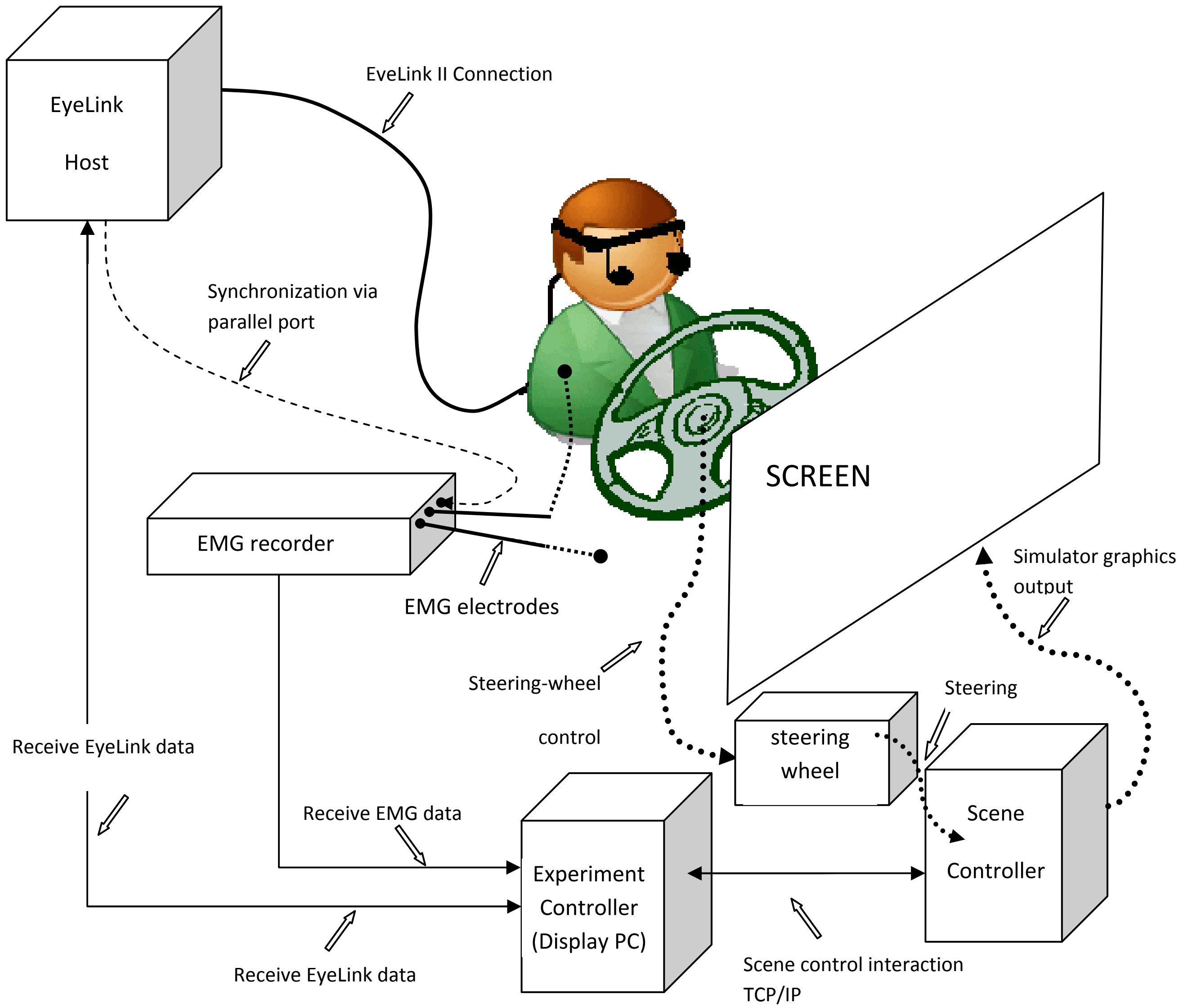


Figure 2. Experimental Set-up

5.4 Experimental Setup

The experimental setup is shown in Figure 2. It has three separate components: scene generation and display, EMG recording, and eye tracker control and recording. Each of these requires coordination and synchronization between them. The initial decision to be made when designing the system was where to locate the central controller that coordinates these components. The in-house SGI scene generation software that was adapted for this project was originally designed as a self-contained experiment control program that ran just on the SGI. Similarly the EyeLink II system came with programs (with source) for running experiments that generated scenarios on the PC monitor and captured only eye tracker data. Either could be used as a basis for controlling our more complex experimental setup. We decided to extend the eye tracker control software on the display PC to be the overall controller. This was done because we had adopted the mechanism of using EyeLink functions for synchronizing the data streams, and also because future work on the project will be off-site where the SGI will not be available.

The architecture of the system is illustrated in Figure 2. There are four computers in the complete system:

1. *Stand-alone steering-wheel control PC (operating system: Microsoft Windows 2000).* This ran proprietary Logitech software that managed the steering wheel and passed position information to the scene generator.
2. *SGI scene controller (o/s: IRIX).* Running the in-house scene generation and control program.
3. *EyeLink II host PC (o/s: DOS).* Running proprietary SR Research software that controlled the eye tracker hardware.
4. *Experiment controller PC (o/s: Microsoft Windows XP).* This ran a LabView data collection program, for EMG data, and the experiment control program, which also managed the EyeLink II display functions (via the EyeLink II library).

The experiment control program communicates with the EyeLink host and the SGI Scene Generator, and collects all the data. The controller also indirectly manages the EMG recorder. It starts the program via system calls, and effects synchronization by requesting that the EyeLink host set/drop its parallel port lines as described above.

5.4.1 Control Program

The top-level control functionality was added to the software that controlled the eye tracker data recording. This software was based on an example program that was supplied with the EyeLink II by SR Research. SR provided this to enable experimenters to develop software to suit their particular deployment situations. The supplied program handled initialization and interactive

calibration of the eye tracker at the start of the experiment, and close down of the eye tracker and automatic downloading of the eye tracker data at the close.

This original framework was extended to coordinate control of generated scenario with the SGI, and also to synchronize with the EMG recorder at the start and end of each generated segment. Coordination with the SGI is via TCP/IP sockets, which are implemented on both Windows and UNIX (IRIX) operating systems. A corresponding socket interface was added to the existing SGI scene generator as a separate asynchronous process.

5.4.2 Test Procedure

The subject's task involved steering along the simulated highway maintaining position in the left-hand lane unless overtaking or avoiding obstacles. Forward velocity was kept constant, meaning that the subjects were not required to regulate their speed, only to steer. Each trial was initiated by the subject pressing a button.

Each test consists of four segments and each segment contains seven obstacles. The sequence and type of obstacles were fixed. Each obstacle was one of the following.

- Overtaking a single vehicle ahead
- Overtaking a single vehicle ahead and finding a second vehicle in front of it which was not visible when commencing the maneuver
- Overtaking a single vehicle ahead and finding an oncoming vehicle in the other lane
- Negotiating blocks strewn across the road
- One of the 3 overtaking tasks with the addition of blocks strewn across the road
- Finding the road completely blocked by a truck broadside-on – this was only used as the last obstacle in the test

In addition to the sequence of obstacles the difficulty of the task was manipulated by varying the speed at which the subject was progressing and also by reducing the forward visibility. The combination of obstacle difficulty, increasing speed, and reduction of visibility was used to make each of the four segments more difficult than the last. The first segment served to familiarize the subject with the basic task, the second was more challenging, the third introduced reduced visibility, and the fourth ended with a completely blocked road.

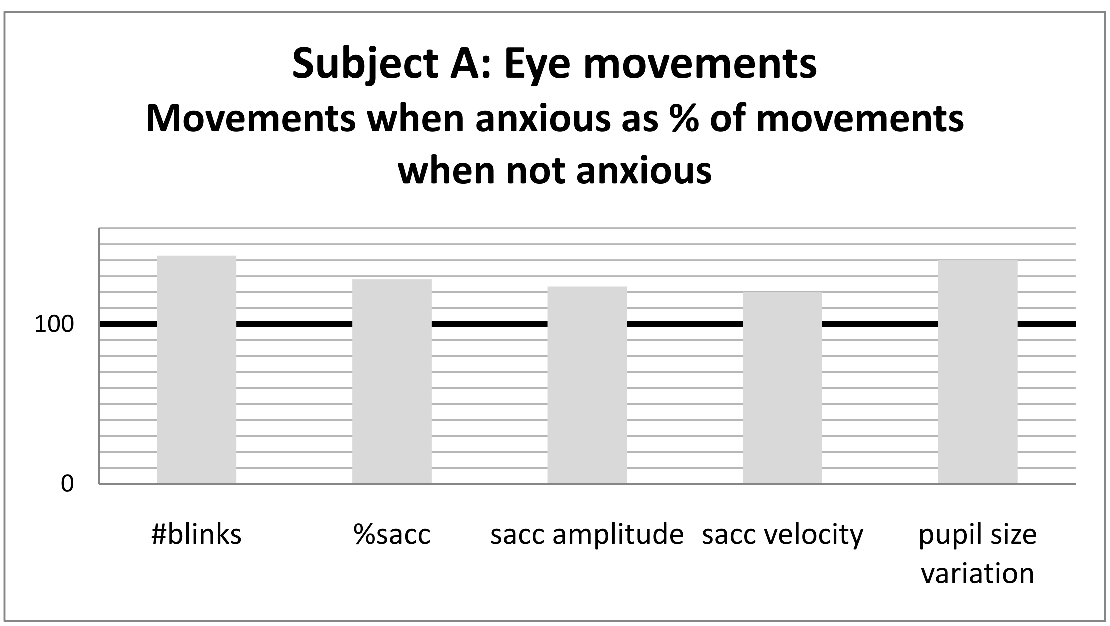
Details of all settings are included in Table 1**,** which also shows the timing of segments and obstacles. Each segment lasted 1 minute 38 seconds so the total driving time was 6 minutes 32 seconds, interrupted by three pauses for the administration of the MAACL-R (Multiple Affect Adjective Checklist-Revised) which was then completed for a fourth and final time on completion of the driving simulation.

Table 1. The sequence of obstacles in the scenario

Sequence	**Speed**	**Visibility Level (1-8)**	**Obstacle type**	**Time at which obstacle is reached**
Start Trial				0
	50	8	Overtake car	11
	50	8	Overtake car	22
	50	8	Overtake 2 cars	36
	50	8	Overtake truck	50
	50	8	Overtake 2 cars	1.04
	50	8	Overtake car	1.18
	50	8	Overtake truck	1.32
End Section 1.				1:38
Subject fills in questionnaire				
Start Section 2				0
	60	8	Overtake truck	8
	60	8	Boxes	22
	60	8	Overtake car	36
	60	8	Overtake car with boxes	50
	60	8	Overtake truck with boxes	1.04
	60	8	Overtake car & meet oncoming car	1.18
	60	8	Boxes	1.32
End Section 2.				1:38
Subject fills in questionnaire				
Start Section 3				0
	70	7	Boxes	8
	70	6	Overtake truck and car	22
	70	5	Overtake car	36
	70	4	Overtake car with boxes	50
	70	4	Overtake truck and car	1.04
	70	5	Overtake truck	1.18
	70	8	Overtake car & meet oncoming car	1.32
End Section 3.				1:38
Subject fills in questionnaire				
Start Section 4				0
	70	7	Overtake car & meet oncoming car	8
	70	6	Overtake truck with boxes	22
	70	5	Overtake truck and car	36
	70	4	Boxes	50
	70	4	Overtake truck with boxes	1.04
	70	4	Overtake truck	1.18
	70	4	Truck across road	1.38
End Trial.				1:38
Subject fills in questionnaire				

6. Results

Previous research has identified a number of parameters relating to the eyes and their movement which are influenced by affective state and specifically state anxiety. Blinks, saccades and pupil dilation have all been reported as varying systematically with manipulations to stress or measured anxiety levels. Chapman et al. (1999) conditioned subjects to expect an electrical shock to their finger-tip, producing raised levels of anxiety and stress. During periods shortly before a shock, the team recorded increases in the cycling of pupil size (i.e. variability in pupil size over time) which they attributed to a rise in anxiety levels. Partla and Surakka (2003) exposed subjects to images designed to produce positive or negative arousal in subjects and reported changes in the maximum, short-term pupil dilatory response which they termed PSV (Pupil size variation). Some tentative links between eye-movement and affective state have also been reported for subjects observing static faces portraying a range of emotional expressions. (Susskind et al. 2008). In particular, the authors report increases in peak saccade velocity in response to fearful expressions. Perhaps one of the more widely investigated measures is blink rate. The general consensus is that blinking increases as anxiety levels increase (e.g. Harrigan & O’Connell, 1996), however the opposite result has also been reported (Liao et al. 2006).

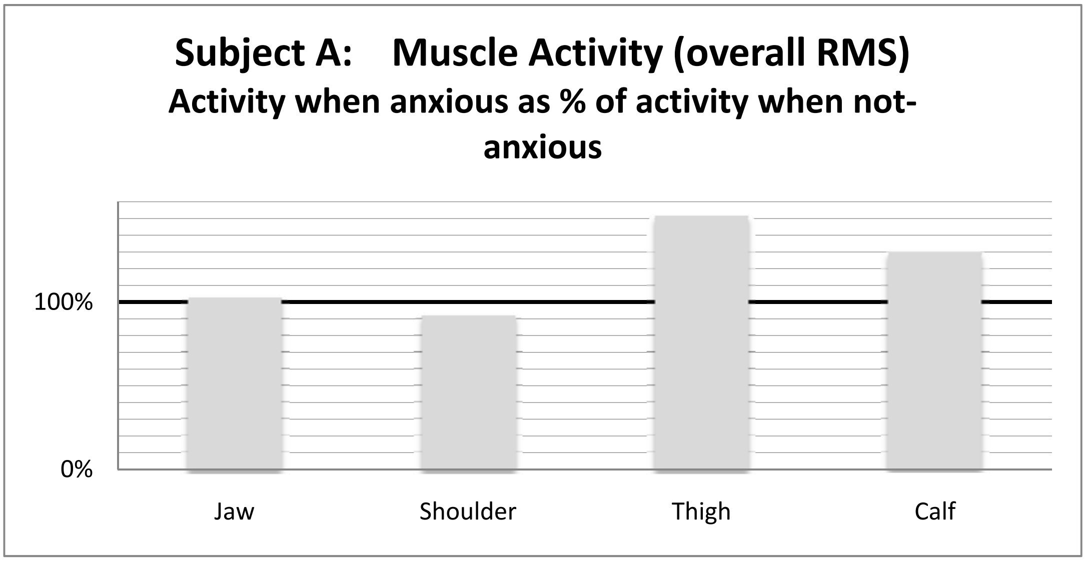


Three of the five subjects tested in the driving simulator reported increasing levels of anxiety in relation to increasing level of task difficulty. In the above graph the results are provided for one subject recorded via eye tracking and pupilometry who reported a systematic increase in anxiety levels via the MAACL-R as the driving task progressed. The measures in each category of eye movement were averaged across periods of low anxiety to form a baseline level. The figures shown in the graph are the measured response, in that category of eye movement, during periods of high anxiety relative to baseline (indicated at 100 on the vertical axis). The categories listed are:

- **#blinks**: total number of blinks during trials in which anxiety was reported.
- **%sacc**: percentage of time spent making saccadic eye movements during trials in which anxiety was reported.
- **sacc amplitude**: average amplitude of saccades during trials in which anxiety was reported.
- **sacc vel**: average velocity of saccades during trials in which anxiety was reported.
- **pupil size variation**: maximum pupil size change over a 4 second window relative to average pupil size over the past ten seconds. By using the running average of pupil size we could discount the effects of pupil dilation in response to changing light levels and other extraneous factors.

The graph reveals an increase in all five measures in this individual as self-reported levels of anxiety increased. The pattern was repeated across the two other subjects who also reported reliable increases in anxiety levels.

Muscular contraction associated with anxiety was measured using EMG. As per the below graph, analysis of the muscle activation patterns of the same participant (subject A) revealed an matching increase in activity associated with anxiety, primarily in muscles of the leg with the level of activation increasing by up to 50% above the non-anxious state. Similar patterns were observed in the other subjects reporting anxiety, who also showed greater amounts of muscle contraction in the jaw, shoulder and wrist as well as the thigh and calf muscles in the higher anxiety state.



7. Discussion

The field of affective computing is still in its infancy. The purpose of the experimental set-up described in this paper was to cast a wide net across a range of physiological measures that could be reasonably expected, based on prior research, to correlate with affective state. By combining standard measures such as blink rate with muscle activation and other eye and head movement data, our aim was to commence the development of an objective tool able to draw out reliable predictors of affective state from combinations of physiological state components. As an important first step, this paper has described how a combination of commercially available eye-tracking and EMG equipment can be linked to provide synchronised data acquisition for affect tracking purposes.

Although the project was unable to undertake Pilot Two which could have be expected to generate higher levels of stress and anxiety as the simulator exposure would have been in a real-world training scenario, we found that even during a lower-anxiety experimental set-up simulation the expected physiological responses to increasing anxiety where significant enough to be clearly captured by the initial pieces of objective monitoring equipment trialled in Pilot One. As outlined in later section 8 in future stages of the project additional pieces of monitoring equipment will be added to the research protocol including face recognition software DeMoLib being currently developed at the Australian National University, EEG, respiration and skin temperature.

7.1 Implications for Affective Skill Theory

Initial findings from Pilot One indicate that, in accordance with prior literature there are relatively robust physiological measures which can be monitored during simulation training to accurately reflect changes in affective states such as anxiety and stress. The development of an objective measurement tool which brings together each of these physiological measures into a real-time affective state monitoring device will provide a new approach to objective measurement of preparedness for high stress operations.

Overwhelmingly to-date affect has been conceptualized in performance theory as a product of how difficult or dangerous a mission is. Yet simulation-based training has been targeting the strengthening and control of affective skills to prepare professionals prior to undertaking missions for decades. Simulators have always been popular in terms of training professionals to 'keep a clear head' in times of crisis. The very nature of simulation training to prepare personnel makes the case that a professional's affective state is not limited to being a by-product of his/her work demands. Simulation has focused on affect because it is acknowledged that intense affect as experienced during stress can negatively affect performance. It can cause overestimation of risks and avoidant choices and also be a distraction when it provides information or motivation to attend to or act on emotional information at the expense of more important content (Peters, Lipkus & Diefenbach, 2006). In elite sports a professional who can control his emotions and purposefully apply them to achieve optimal performance outcomes is described as being 'mentally tough' (Gordan & Gucciardi, 2010; Gucciardi & Gordon, 2009).

A theoretical framework which supports the study of affect within the context of professional training for optimum performance under high stress conditions will assist in the investigation of such research questions as: Can a level of "expert affective skill" at which best performance outcomes are achieved on target tasks be ascertained. Can the 'expert affective skill level be used as a benchmark against which a novice's affective performance can be measured to ascertain whether affective levels need to be increased or decreased to support best performance outcomes?

The design of simulation training provides the best test environment for AST. Once specific objectives for training have been identified, specialized mission scripts and trigger events are developed. A trigger event is designed to elicit a specific response from a trainee. instructional designers work with subject matter experts to identify critical behaviors that should unfold after a trigger event. . The instructor knows for any given moment in a scenario what objectives are being trained, what trigger events are about to occur, and what behaviors are critical to mission success (Bennett, Schreiber & Andrews, 2002).

The original goal of the AOARD 104011 project was to explore the role of affect in objective training evaluation. Through the development of the AST theory to explain and support the research design it became evident that AST through conceptualizing affect as an objective measureable professional skill could also be extended to provide a method of representing

affective workload at the overall mission level which could then be developed into a predictive affective workload measure to support operational planning. Predictions of operation success can be modeled based on the ability to assess the match between the overall operational affective requirements with the individual affective skill levels of personnel.

In practice how this will occur is measurements of an individual's affective skills, taken by the objective physiologically-based tool during simulation training, will be integrated with a computational performance prediction model which plots affect, effort and task demands at the overall mission level. The first trial of the Affective Skills Theory in the area of operational planning will match the individual affective skill level of professionals undertaking an identified simulation task which will then be matched by affective workload predictions made for that same task using the computational version of the compensatory control model currently under development. This application is discussed further in the following section 7.3.

7.3 The role of Affective Skill Theory in Prediction/Operational Planning.

A number of workload prediction models have been developed are in use. Predictive workload measures use models that represent workload for the purpose of prediction. These generally analyze a task/workload based on multiple resource theory of human attention, resulting in estimates of the cognitive, psychomotor, and sensory components of workload for each task. The theory underlying TAWL methodology recognizes five independent workload components: auditory, kinesthetic, visual, cognitive, and psychomotor (Hamilton & Cross 1993). The ARL-HRED's Improved Performance Research Integration Tool (IMPRINT) model uses the visual, auditory, cognitive and psychomotor model (VACP) to estimate workload based on scales developed by McCracken and Aldrich (1984). To our knowledge no current prediction models analyze the affective cost of an operation.

Real-time monitoring of individuals for affective skill capacity via an approach based on sampling multiple neurophysiologic signals, and integrating those signals with performance prediction models able to estimate the affective component of workload, potentially provides a method of supporting commanders and control personnel. AST identifies a new measure of performance through integrating affective skills into a model predicting operational performance this will enhance the quality and quantity of information supporting decision making at the operational level.

The ability to control affect in a manner that uses emotion to improve performance is a trainable skill. Affective skills are integral to success as affect moderates human performance in ways that are sometimes difficult to predict. The positive or negative effects of a single affective event may depend on operational context, individual perception or degree. For example a small amount of fear might encourage a runner to run faster, but a large amount of fear might make him unable to run at all (Redden et al, 2004).

The Affective Skill Theory developed in the first phase of the current AOARD project supports the future development of a predictive workload measure able to estimate affective workload. AST conceptualizes affect as a professional skill that can be trained prior to an operation and can

also therefore be used as a key variable in evaluating operation success based on the ability to assess the match between the affective resources of personnel with affective requirements necessary for success at the operational level.

The development of a theoretical model that conceptualizes affect as skill necessary to successfully undertake task demands has significant potential to assist command and control in the area of operational planning. For example, a model of task workload which accounts for affective output (the affective costs of a deployment) will support the identification of situations in the field which will impose high affective task demands on personnel. When an operation has been identified as high affective demand, the optimal affective level of expertise required of personnel to successfully complete the operation can be estimated. Ultimately such a theoretical model that facilitates the mapping of affective requirements and cost with task demands could assist in predictions of overall mission success and in the planning of additional training requirements.

Affective state is a key variable within a computational prediction model currently being developed. The predictive computational affect workload model (CAWM) will ultimately be able to offer predictions about the relationships between task demands, task performance, affect and their impact on goal achievement. The innovation of the CAWM is to develop a quantitative model which translates the qualitative compensatory control model of human performance under stress and high workload (Hockey, 1997) into a computational form. The compensatory control model proposes that physiological and affective responses are inherent in the regulatory process. Previously psychological models (such as the compensatory control model) have been based on verbal descriptions of the relationships between variables. These models allow qualitative descriptions about human performance, but do not allow quantitative assessments to be made. Thus the initial step in developing a quantitative model is to translate the existing qualitative theories into a computational form. The initial step in the development of the computational model CAWM is forcing the parameters of the compensatory control model to be precisely identified and defined to allow the translation of the existing qualitative theory into the computational form (Fletcher, 2010). The representation of relationships between task/overall mission variables as mathematical functions provides the means of identifying situations where excessive levels of task demands exist. While the model is not limited to the variable of affect this workload variable can be plotted over time.

In summary, the Affective Skill Theory provides a new approach to comparing personnel affective skills levels with mission affective requirements. The current AOARD 104011 project commenced the work to develop an objective real-time monitoring tool that will quantitatively assess individual personnel's affective levels during a simulated task. The CAWM can then be used to plot the variables, including affect, of a required operation over time and determine the level of affective skills required to reach goal achievement. If the model highlights a mismatch between personnel affective resources and affective skills necessary for mission success the framework will in fact pinpoint type and degree of affective training requirements pre-deployment to ensure a professional affective skill and mission match.

8. Future Research Directions

Pilot One commenced with EMG, pupilometry and feature extraction methods of monitoring physiological responses to affective states. In this experiment anxiety, as measured by the MAACL-R, was the affective state most strongly associated with the experimental simulation task. Now that proof of concepts and physical equipment trialing has been achieved the future phases of the project will be the addition and trialing of further physiological monitoring devices. The larger and more varied the final data set the greater the ability of the objective affect measurement tool (OAMT) to differentiate between individual target affective states. The new devices to be trialed include:

8.1 Face Tracking via DeMoLib

Facial expressions are a major component in judging person’s affective state (Asthana, Sargih, Wagner & Goecke, 2009). Muscle movements involved in fear include raising eyebrows and drawing them together, and/or stretching the lips horizontally so that the lips form a rectangular mouth shape. In more extreme states of fear, a raised, tensed upper eyelid which widens the eye is also evident (Harrigan & O’Connell).

Dr Roland Goecke, Head of Vision and Sensing Group at the University of Canberra, Australia will be providing his developmental software DeMoLib for testing with the OAMT application. The system will be used posthoc initially with transition into real-time monitoring in later stages.

8.2 EEG

New brain imaging technologies are opening the windows to new ways of looking at affective states (AlZoubi, Calvo, Stevens, 2009). Some previous studies have used a combination of EEG and other physiological signals, while others used EEG solely for affect detection. A recent study focussing on the automatic classification techniques that could be used for EEG data showed that accuracies well above the baseline are possible. This new, exploratory science will be investigated for correlations with the other measures in use in the project.

8.3 Bioharness

While feature extraction and eye-tracking are the focus of the project, the end goal is to provide multiple measures to yield independent and converging evidence of affective states. For that reason, the study will also include several physiological measures (in addition to EMG). Physiologists demonstrate that high stress level is accompanied with the symptoms of faster heart beat, rapid breathing, increased sweating, cool skin, feelings of nausea, tense muscles and alike. (Liao, Zhang, Zhu & Ji, 2005). We have purchased a Zephyr BioHarness for use in this project. It uses wireless technology to provide real-time data on heart rate, respiration and skin temperature. It will be trialed for the first time when Pilot Study Two is undertaken.

8.4 Linking Affect to Perceptual Processing

If one wishes to synchronise external scene events with emotional response, a record of those events is required. The eye tracking system we are using has the advantage that it can also record the scene observed by the participant via a head-mounted camera. Eye tracking data is rendered onto the camera’s video stream as a small fixation cross and this video is automatically synchronised with the eye movement data. This allows offline matching of salient visual events (e.g. obstacle appears, target acquired) with the physiological data.

People can learn to distinguish between task-relevant information and task-irrelevant information (Sohn, Douglass, Chen & Anderson, 2000). Through eye-tracking data, learning should be reflected in the pattern of attention distribution or eye fixation. In simulation training we want to know what is happening with participant’s perceptual processes at specific decision points within the scene and the subsequent impact of evoked emotion. In successful training participants should learn to pay more attention to on-task regions relative to off-task regions (Sohn et al, 2000). If the training is properly designed, eye-movement data should show that users look at irrelevant regions less and less as they practice more.

We propose that by monitoring affective state while simultaneously tracking people’s perceptual processing was can ascertain the impact of stress at different decision points. It is expected that high affect levels of negative may negatively influence visual processing of cues. For example when angry, a person may focus for less time on an important cue they had spent far longer visually processing during an earlier training session. The ability to synthetically evoke intense

affective states during a complex cognitive task allows accurately timed measurement of user responses and will help to answer such questions as is there an optimal degree of affective intensity which supports the laying down of a long term memory trace but over which intensity level cognition degrades? Such insights will assist the development of a model to guide use of eye movement monitoring to evaluate high affect training in virtual environments.

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